ANATOMICAL ADAPTATIONS FOR A FOSSORIAL EXISTENCE IN THE STAPHYLINID BEETLE, *OSORIUS PLANIFRONS* (COLEOPTERA: STAPHYLINIDAE)

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Abstract

A study of the external anatomy of *Osorius planifrons* LeConte revealed that these animals possess several structural adaptations to fossorial life. These include a nearly cylindrical shape, shortened appendages, expanded digging tibiae, reduced tarsi, mandibles modified for digging and carrying sand grains, and setae around the mouth. The oral setae are apparently functional analogs to ammochaetae which occur on certain fossorial ants. We discuss the possible origins of these adaptations.

Moore and Legner (1974) indicated that rove beetles belonging to the subfamily Osoriinae are usually found in the sandy margins of streams, and Blatchley (1910) has likewise found them "beneath stones and logs in damp places." Kirk (1969) says *Osorius planifrons* LeConte has been collected at broomsedge (*Andropogon scoparius* Michaux or *A. virginicus* L.) in South Carolina. He notes that considerable amounts of organic debris mixed with windblown inorganic matter accumulates in the crown area of this grass. If the variety of broomsedge is *abbreviatus*, it grows in wet soil along the coastal plain. Recently, we (Smith *et al.* 1978) studied the ecology and behavior of *Osorius planifrons* on golf course greens and in the laboratory. Under suitable conditions, these insects occurred in dense aggregations and completed their life cycle in subterranean galleries, with adults leaving the ground to disperse and mate. *O. planifrons* apparently requires moist sandy soil containing particulate organic material. Adults and larvae probably subsist on soil microbes. This species burrowed continuously in raw sand in the laboratory. We interpreted burrowing to be an appetitve search for detritus containing microbial food.

While observing the burrowing behavior of these insects, we noted that adults seemed to possess a number of anatomical adaptations to fossorial life. Consequently, we studied the external morphology using light and scanning electron microscopy. The purpose of this communication is to depict and briefly discuss the function and possible origin of these external anatomical adaptations.

Methods

Live *O. planifrons* were collected in golf course greens at the Tucson Country Club in northeast Tucson, Arizona, and returned to the laboratory where they were observed with a dissecting microscope in sand-filled narrow glass terraria (290 mm^2 × 8 mm ID). Individual specimens were killed in 70% ETOH, mounted on aluminum pegs with double stick cellophane tape, vacuum-coated with gold palladium, and observed with an Etec^R scanning electron microscope. Scanning electron micrographs were produced with type 55 pos-neg Polaroid[R] film. Enlargements were produced from the negatives.

Results

Gross Anatomy

Figure 1A displays the gross external anatomy of *O. planifrons*. We noted that the three body regions of this species are cylindrical and that the largest cross-sectional diameter of head, thorax, and abdomen are ap-

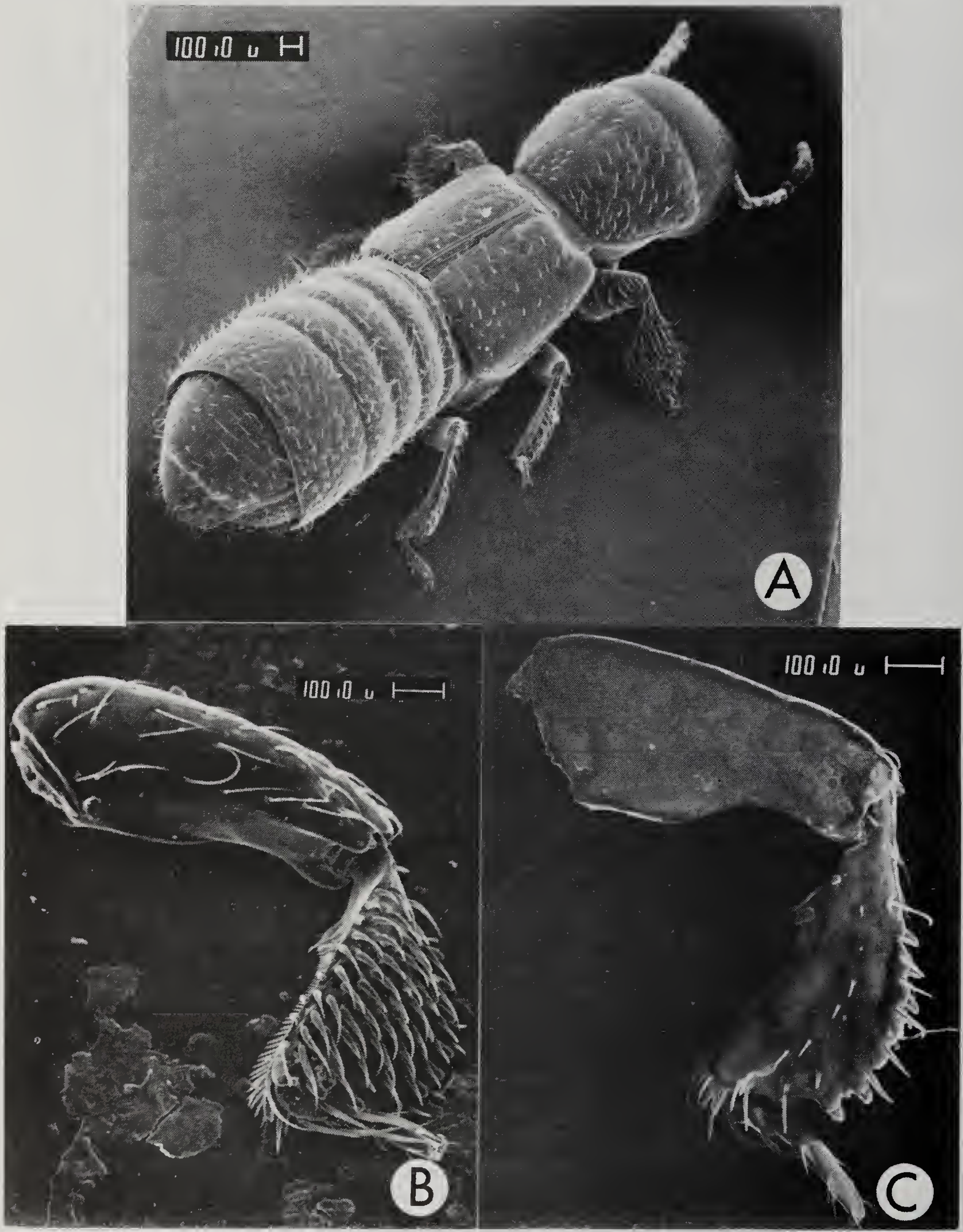

Figure 1. Scanning electron micrographs of the gross anatomy and front legs of *Osorius planifrons*. A. *O. planifrons* whole mount; B. Posterior surface of right front leg; C. Anterior surface of left front leg.

proximately equal. We suppose the cylindrical body form has evolved to permit unobstructed movement through tunnels only slightly larger than the insect's cross-section.

Legs

The legs of *O. planifrons* are relatively short and held close to the body, with the length of the femora extending only about 200 μm beyond the lateral margin of the thorax when perpendicular to the body axis. The meso- and metafemora are flattened and concave so that the curvature conforms to the side of the body. The profemora are short, but robust. They move in an arc that only slightly exceeds the lateral margin of the body within the space between the pro- and mesothorax. The protibiae are greatly enlarged, spatulate, and furnished with stout teeth (resembling those on a mechanical backhoe) on the lateral margin (Fig. 1A, B, C). The tarsi are extremely delicate structures that serve no observable function in the subterranean activities of the beetles. They use the front legs for digging at the surface to initiate new burrows. When so employed, the protibiae are locked into the groove in the profemora (Fig. 1B) and the tarsi are drawn into and protected by the anterior marginal tibial teeth. The result is that the front legs become extremely stout and efficient digging organs which are used to drag material from beneath the animal, forming the depression from which a burrow is initiated. The posterior face of the protibiae and the anterior face of the meso- and metatibiae are adorned with approximately 60 sharp conical spines ranging in length from 50 to 100 μm (Fig. 1B). These surfaces are used for locomotion within tunnels. The protibiae are employed to hold the beetle securely in place when it is working the blind end of a tunnel or pushing a casting from the entrance of the tunnel network. The spines apparently enter the interstices between sand grains, providing the necessary traction.

Head

The head of *O. planifrons* is knob-shaped and broadly joined to the prothorax as a ball in socket (Fig. 1A). The eyes protrude only slightly from the lateral margin of the head, and the antennal scapes extend no wider than the posterior portion of the head. When the antennae are folded posteriorly, the distal segments do not extend beyond the front of the head. The cephalo-prothorax is used as a unit to push loosely packed plugs of sand from the burrow entrance, forming vermiform castings on the surface (see Smith *et al.* 1978). The broad ball-in-socket attachment of head and prothorax presumably evolved under selection for rigidity and strength to facilitate this task.

Mouthparts

The mandibles of *O. planifrons* are not flat and sharp with overlapping points as are those of predaceous rove beetles. They are concave, spoon-shaped, and blunt at the tips (Fig. 2A, B, C, D). Our observations (Smith *et al.* 1978) suggest that these structures are employed to move soil particles and carry grains of sand exclusively. They have apparently lost their predatory and feeding functions. Feeding on detrital particles is apparently accomplished by the labral combs (Fig. 2A) sweeping material into the oral cavity when the mandibles are spread. The labrum, maxillae, and labium (Fig. 2B) function in sand-grain carrying and probably also in feeding.

Oral Setae

Of special significance are groups of long slender setae on the premen-

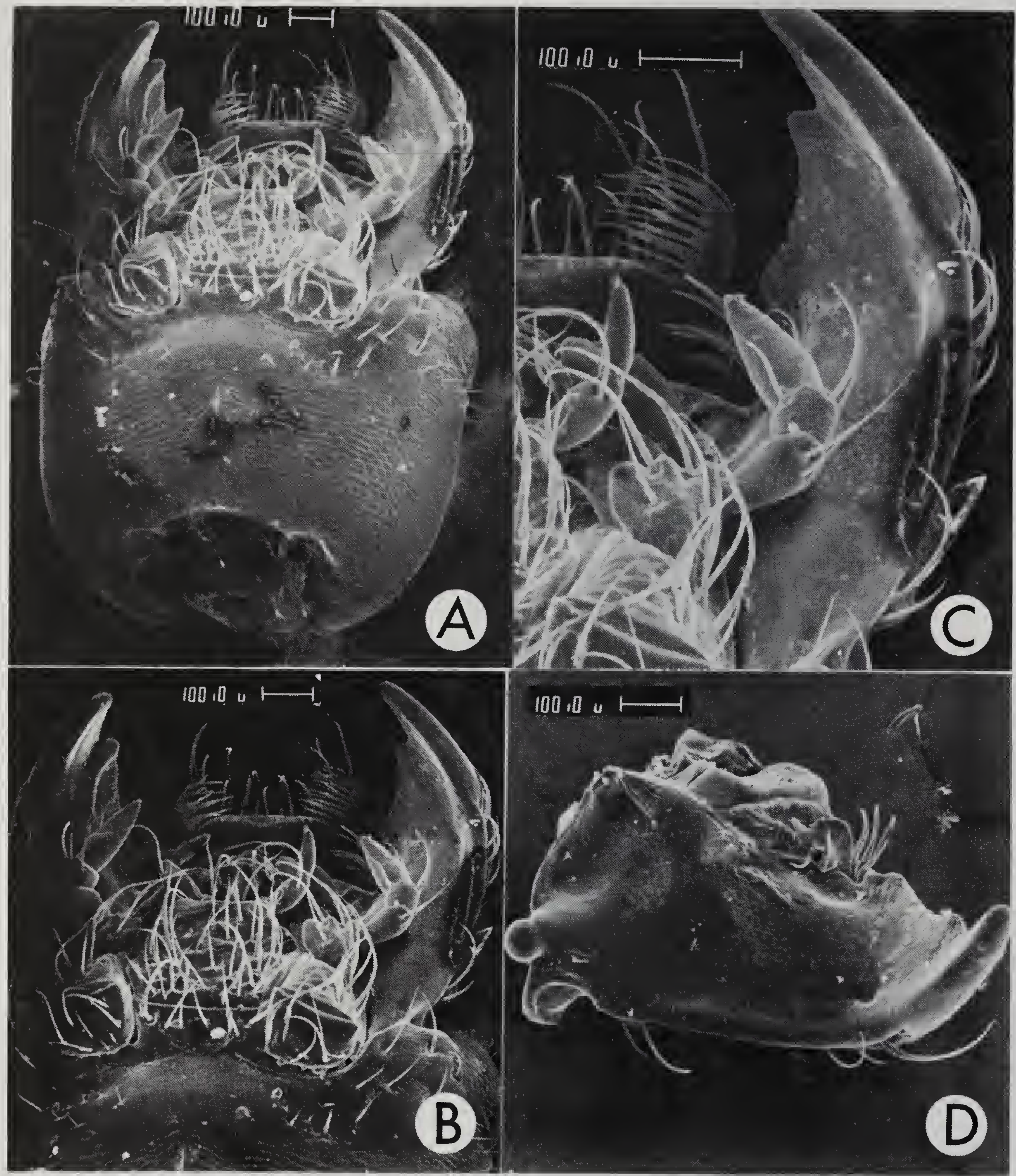

Figure 2. Scanning electron micrographs of the ventral aspects of the head and mandibles of *Osorius planifrons*. A. Ventral aspect of head; B. & C. Successive enlargements of mouthparts; D. Ventral aspect of the disarticulated left mandible.

tum, mentum, and gula of this species (Fig. 2B). These setae are analogous to the ammocaetae reported on ants belonging to three subfamilies: Myrmicinae, Formicinae, and Dolichoderinae (Wheeler 1907, 1910). Santschi (1909) and Spangler and Rettenmeyer (1966) have demonstrated that the primary function of ammochaetae in ants is to carry sand or soil while excavating nests. The setae on *O. planifrons* are not as highly developed as those on ants, but we propose an analogous function. Although our observations are not as detailed as Spangler and Rettenmeyer's, we did observe *O. planifrons* to behave in a fashion similar to that described for *Pogonomyrmex occidentalis* when beginning an excavation. Specifically, the ventral surface of the head was pushed forward in the substrate and then drawn back to the rim of the excavation as if to secure materials in the setae and then to deposit them at the rim. Furthermore, we observed individuals in subterranean networks to shape the walls of their tunnels using the ventral portion of the head. It appeared that these individuals removed material from high spots and carried it to slight depressions where it was apparently brushed from the setae and packed into place.

Discussion

Beetles belonging to the family Staphylinidae are generally thought to be predaceous members of decaying organic matter communities (Borror, DeLong, and Triplehorn 1976). Species representing two genera in the subfamily Osoriinae (see Moore 1964), *Neotrochus* and *Fenderia*, lack most of the fossorial adaptations characteristic of the genus *Osorius* and may occupy niches similar to the majority of species in the family. Members of the genus *Osorius* (as exemplified by *O. planifrons*) are clearly fossorial animals that may have become specialized for digging in soil beneath decaying matter, perhaps to escape interspecific competition. It is tempting to suggest that a shift in food habits from predatory to detritivory accompanied the divergence of *Osorius* from some rotting-wood-dwelling ancestor. This might have occurred in response to the lower abundance of potential prey in sandy soil. Unfortunately, the food habits of *Neotrochus* spp. and *Fenderia* spp. are unknown.

At any rate, the shift to fossorial life by *Osorius* was accompanied by anatomical adaptations including cylindrification of the body, shortening of appendages, enlargement of the tibiae into efficient digging organs, and the elaboration of cuticular spines and setae for digging and carrying soil particles. Oral setae seem to be convergent with similar structures in fossorial ants. The change in food habits, whenever it occurred, apparently released the mandibles of *Osorius* from their primary ancestral predatory function and allowed them to become modified exclusively for digging and carrying sand grains.

The biology of other species of rove beetles in the subfamily is little known. Perhaps studies of the ecology and food habits of other species will reveal evolutionary intermediates between this remarkable fossorial detritivore and some predaceous rotting-wood-dwelling ancestor.

Literature Cited

Blatchley W. S. 1910. An Illustrated Descriptive Catalogue of the Coleoptera or Beetles (Exclusive of the Rhynchophora) Known to Occur in Indiana. Nature Pub. Co., Indianapolis. 1385 pp.

Borror, D. J., D. M. DeLong and C. A. Triplehorn. 1976. An Introduction to the Study of Insects. Holt, Rinehart and Winston, Inc., New York. 825 pp.

Kirk, V. M. 1969. A list of the beetles of South Carolina, Part I—Northern coastal plain. South Carolina Agric. Exp. Sta. Tech. Bull. 1033. P. 23.

Moore, I. 1964. A new key to the subfamilies of the Nearctic Staphylinidae and notes on their classification. Coleopt. Bull. 18:83-91.

Moore I. and E. F. Legner 1974. The genera of the Osoriinae of America north of Mexico. Coleopt. Bull 28:115-119.

SANTSCHI, F. 1909. Sur la signification de la barbe des fourmis arenicoles. Rev. Suisse Zool. 17:449-458.

SMITH R. L., G. C. LANZARO, J. E. WHEELER AND A. SNYDER. 1978. Ecology and behavior of *Osorius planifrons*. Ann. Entomol. Soc. Amer. 71:752-755.

SPANGLER, H. G. AND C. W. RETTENMEYER. 1966. The function of the ammochaetae or psammophores of harvester ants *Pogonomyrmex* spp. J. Kansas Entomol. Soc. 39:739-745.

WHEELER, W. M. 1907. On certain modified hairs peculiar to ants in arid regions. Biol. Bull. 18:k85-202.

WHEELER, W. M. 1910. Ants, their Structure, Development and Behavior. Columbia Univ. Press, New York. 663 pp.

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